TRANSVERSE ELEMENT HAVING A DISTANCE SURFACE BETWEEN A SUPPORTING SURFACE AND A PULLEY SHEAVE CONTACT SURFACE

BENEFIT CLAIM

This application claims the benefit of Dutch Patent Application No. 1022072, filed 3 December 2002.

FIELD OF THE INVENTION

The present invention relates to a transverse element for a push belt for a continuously variable transmission, comprising: a supporting surface for supporting a carrier of the push belt; a pulley sheave contact surface which is destined to abut against a contact surface of a pulley sheave of a pulley of the continuously variable transmission; and a transition edge region which is connected to the supporting surface on the one hand, and which is connected to the pulley sheave contact surface on the other hand.

BACKGROUND OF THE INVENTION

Such a transverse element is generally known, and is destined for application in a push belt of a continuously variable transmission. Such a push belt comprises two sets of rings which function as carriers of a number of transverse elements. These rings are relatively flat and wide, i.e. the radial distance between an inner circumference and an outer circumference of the rings is relatively small with respect to the dimension in the axial direction. The transverse elements are continuously arranged along the entire circumference of the rings, so that they are able to transmit forces which are related to a movement of the push belt during operation.

In the following description of a transverse element, the mentioned directions refer to the situation in which the transverse element is part of the push belt. A longitudinal direction of the transverse element corresponds to a circumferential direction of the push belt. A vertical transverse direction of the transverse element corresponds to a radial direction of the push belt. A horizontal transverse direction of the transverse element corresponds to a direction perpendicular to both the longitudinal direction and the vertical transverse direction. Furthermore, a side of the transverse element, which in the push belt is situated at the outer circumference, is considered as upper side of the transverse element, whereas a side of the transverse element, which in the push belt is situated at the inner circumference, is considered as under side of the transverse element.

In the longitudinal direction, the transverse element has small dimensions, in other words, the transverse element has a small thickness. A front surface and a back surface of the transverse element extend in the horizontal transverse direction and in the vertical transverse direction. A standing surface which is situated between the front surface and the back surface will hereinafter be referred to as circumferential surface of the transverse element.

On both sides, the transverse element is provided with recesses for at least partially receiving the rings. For the purpose of supporting the rings, the transverse element comprises supporting surfaces.

Furthermore, for the purpose of contact between the transverse element and the pulley sheaves of the continuously variable transmission, the transverse element is on both sides provided with pulley sheave contact surfaces, which are divergent in the direction of the supporting surfaces. A supporting surface and a pulley sheave contact surface which are situated at one side of the transverse element are interconnected through a convexly curved transition surface.

In the vertical transverse direction, the transverse element comprises successively a basic portion, a neck portion and a top portion, wherein the dimensions of the neck portion in the horizontal transverse direction are considerably smaller than the dimensions of the basic portion and the top portion, respectively, in the horizontal transverse direction, in other words, the neck portion is relatively narrow. In the push belt, the basic portion is situated at the side of the inner circumference of the push belt, whereas the top portion is situated at the side of the outer circumference of the push belt. The supporting surfaces and the pulley sheave contact surfaces are part of the basic portion.

The transverse element is formed out of a basic product which is obtained by means of blanking. The surface of the basic product is post-treated with the help of a tumbling process, wherein the basic product is intermittently put in contact with tumbling stones. During this post-treatment process, a number of basic products and a number of tumbling stones move continually around each other. The basis products touch each other *inter alia* at the place where the supporting surface and the pulley sheave contact surface are interconnected. Research has shown that in this way, in the immediate vicinity of this place, protrusions may be developed, which protrude above the level of the supporting surface. This may also happen during other processes, for example during sorting of the transverse elements, wherein the transverse elements also collide with each other, or during blanking of the basic products, wherein the blanked products land on a surface of a receiving

sheet. When the rings are inserted in the recess in the transverse element and are laid on the supporting surface during the manufacture of the push belt, the rings may be damaged by the protrusions. Also, during operation of the push belt, damage of the rings may occur, when the rings continually come into contact with the protrusions. It has appeared in practice that in case of a protrusion being higher than 15 μm with respect to the supporting surface, the rings are often damaged in such a way that the life span of the push belt is considerably shortened, as a result of the fact that the carrier prematurely breaks.

It is an objective of the present invention to provide a transverse element having such a shape that protrusions, which are developed as a result of situations in which the transverse element collides with a relatively large collision element like another transverse element, are not capable of inflicting damage on the rings. What is meant by a relatively large collision element is an element having such dimensions that it is capable of simultaneously touching the basic portion and the top portion of the transverse element.

According to an important aspect of the present invention, the transition edge region comprises a concave portion.

Due to the fact that the transition edge region of the transverse element according to the present invention has a concave portion, it is possible that this transition edge region comprises a sub-region contiguous to the pulley sheave contact surface, which is situated such that in case of a collision of the transverse element with a relatively large collision element, protrusions are developed exclusively in this sub-region, wherein, in addition, these protrusions are not capable of extending above the level of the supporting surface. In that case, the protrusions are not capable of inflicting damage on the rings. It is of importance that a distance between the supporting surface and the sub-region, which is measured along the surface, is sufficiently large for preventing the development of protrusions on the supporting surface itself. At the same time, it is of importance that a height difference between the supporting surface and the sub-region is sufficiently large for preventing the protrusions from extending above the level of the supporting surface.

Within the scope of the present invention, an embodiment is possible, wherein the above-mentioned sub-region of the transition edge region comprises a completely flat distance surface, which, on the one hand, is connected to the pulley sheave contact surface, through a rounded off surface, and which, on the other hand, is connected to the concave portion. The dimensions of the

distance surface in the horizontal transverse direction may be chosen such that a tangent plane which touches the circumferential surface of the transverse element at both the basic portion and the top portion, and which thereby is representative of the way in which a relatively large collision element touches the transverse element, touches the basic portion at the rounded off surface. In that case, the distance between the supporting surface and the rounded off surface is sufficiently large for preventing protrusions from developing outside the distance surface and from extending above the level of the supporting surface.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be explained in more detail on the basis of the following description of a preferred embodiment of a transverse element according to the invention with reference to the drawing, in which equal reference numerals indicate equal or similar parts, and in which:

Figure 1 is a diagrammatical side view of a continuously variable transmission having a push belt;

Figure 2 is a front view of a transverse element according to a preferred embodiment of the present invention;

Figure 3 is a side view of the transverse element which is shown in **Figure 2**; and

Figure 4 shows a detail **Z** of the transverse element which is shown in **Figure 2**.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Figure 1 diagrammatically shows a continuously variable transmission, such as for utilization in a motor vehicle. The continuously variable transmission is indicated in general by the reference numeral **1**.

The continuously variable transmission **1** comprises two pulleys **4**, **5** being arranged on separate pulley shafts **2**, **3**. An endless push belt **6**, which is shaped like a closed loop, is arranged around the pulleys **4**, **5** and serves for transmitting torque between the pulley shafts **2**, **3**. Each of the pulleys **4**, **5** comprises two pulley sheaves, wherein the push belt **6** is positioned and clamped between said two pulley sheaves, so that a force may be transmitted between the pulleys **4**, **5** and the push belt **6**, with the help of friction.

The push belt **6** comprises at least one endless carrier **7**, which is usually composed of a number of rings **8**. Along the entire length of the carrier **7**, transverse elements **10** are arranged,

wherein the transverse elements **10** are mutually adjacent to each other. For the sake of simplicity, only a few of these transverse elements **10** are shown in **Figure 1**.

Figures 2 and **3** show a transverse element **10**. A front surface of the transverse element **10** is indicated in general by the reference numeral **11**, whereas a back surface of the transverse element **10** is indicated in general by the reference numeral **12**. A portion of the surface of the transverse element **10**, which is situated between the front surface **11** and the back surface **12**, is hereinafter referred to as circumferential surface **25**.

In the vertical transverse direction, the transverse element **10** comprises successively a basic portion **13**, a relatively narrow neck portion **14** and a top portion **15** which is shaped like the tip of an arrow. In the push belt **6**, the basic portion **13** is situated at the side of the inner circumference of the push belt **6**, whereas the top portion **15** is situated at the side of the outer circumference of the push belt **6**.

At the place where the basic portion **13** of the transverse element **10** is connected to the neck portion **14**, said basic portion **13** comprises two supporting surfaces **16** which serve for supporting two carriers **7**. Furthermore, the basic portion **13** comprises two pulley sheave contact surfaces **18**. When the transverse element **10** moves over the pulley **4**, **5**, contact between the transverse element **10** and contact surfaces of the pulley sheaves is established through said pulley sheave contact surfaces **18**.

The supporting surface **16** is not of a completely flat design, but has in a somewhat convex shape in a plane perpendicular to the longitudinal direction, whereby the carrier **7** will centre itself on said supporting surface **16** during operation of the continuously variable transmission **1**. The radius of the curvature of the supporting surface **16** is so large that no expression is given to said curvature in the figures. The value of the radius of the convex curvature of the supporting surface **16** may vary along the supporting surface **16**.

On the front surface **11** of the transverse element **10**, a tilting line **20** is defined. The tilting line **20** is situated at the basic portion **13**, and, in the shown example, extends along the entire width of the transverse element **10**. In **Figure 3**, it can be seen that in this example, the tilting line **20** is situated at a convex transition region between a portion **21** of the front surface **11**, which is inclined with respect to the back surface **12**, and a portion **22** of said front surface **11**, which extends substantially parallel to the back surface **12**. An important function of the tilting line **20** is

guaranteeing mutual contact between adjacent transverse elements **10** when said transverse elements **10** move over one of the pulleys **4**, **5** during a movement of the push belt **6**, for example.

At the front surface **11** of the transverse element **10**, a projection **23** is arranged. In the shown example, the projection **23** is located at the top portion **15**, and corresponds to a hole in the back surface **12**. In **Figure 3**, the hole is depicted by means of dashed lines, and indicated by the reference numeral **24**. In the push belt **6**, the projection **23** of the transverse element **10** is at least partially located inside the hole **24** of a subsequent transverse element **10**. The projection **23** and the corresponding hole **24** serve to prevent mutual displacement of adjacent transverse elements **10**, in a plane perpendicular to the circumferential direction of the push belt **6**.

In **Figure 2**, an imaginary tangent plane **26**, which touches the circumferential surface **25** of the transverse element **10** at both the basic portion **13** and the top portion **15**, is diagrammatically depicted by means of a dash and dot line. This tangent plane **26** is representative of the way in which a relatively large collision element touches the transverse element **10**.

In a phase of the manufacturing process of the transverse element **10**, the transverse element **10** is subjected to a tumbling process, for the purpose of removing any unevenness from the surface of the transverse element **10**. During this process, the transverse element **10** is intermittently put in contact with tumbling stones, wherein a number of transverse elements **10** and a number of tumbling stones move continually around each other. During the tumbling process, the transverse elements **10** touch each other, from all kinds of directions, at all kinds of places. One possibility is that a transverse element **10** touches another transverse element **10** at the place where the tangent plane **26** also touches.

In a transverse element **10** according to the state of the art, an imaginary tangent plane as described in the foregoing touches a curved transition surface, which is located between the supporting surface **16** and the pulley sheave contact surface **18**. When a collision element touches the transverse element **10** at a place which is also touched by the tangent plane **26**, protrusions may be developed, which extend above the level of the supporting surface **16**. During the manufacture of the push belt **6**, a bottom ring **8** of the carrier **7** may be damaged by these protrusions when the carrier **7** is inserted in the space between the basic portion **13** and the top portion **15**, and is laid on the supporting surface **16**. Damage of the bottom ring **8** may also occur during operation of the push

belt **6**. Even in case of the protrusions having a height of just a few micrometers, the bottom ring **8** may already be damaged to such an extent that the life span of the push belt **6** is shortened.

An important difference between the transverse element **10** according to the present invention and the transverse element according to the state of the art relates to the design at the transition of the supporting surface **16** to the pulley sheave contact surface **18**, and is illustrated by means of **Figure 4**. A region which is located between the supporting surface **16** and the pulley sheave contact surface **18** is hereinafter referred to as transition edge region **40**.

As has already been remarked in the foregoing, in the transverse element according to the state of the art, the supporting surface **16** and the pulley sheave contact surface **18** are interconnected through a curved transition surface. In **Figure 4**, this curved transition surface is depicted by means of a dashed line and indicated by the reference numeral **30**. An imaginary tangent plane, which touches the circumferential surface **25** of the transverse element at both the basic portion **13** and the top portion **15**, touches the basic portion **13** at the curved transition surface **30** between the supporting surface **16** and the pulley sheave contact surface **18**. In **Figure 4**, this tangent plane is depicted by means of a dash and dot line, and indicated by reference numeral **31**. A tangent line between the tangent plane **31** and the transition surface **30** is indicated by the letter A.

The transverse element **10** according to the present invention comprises a curved transition surface **17**, which is connected to the supporting surface **16**. In the shown example, the shape of this transition surface **17** is comparable to the shape of the transition surface **30** of the transverse element according to the state of the art, as becomes apparent from **Figure 4**. The curvature of the transition surface **17** is convex, wherein the transition surface **17** is declined in the direction of the tilting line **20**, starting from the supporting surface **16**.

According to an important aspect of the present invention, a distance surface **41** is located between the transition surface **17** and the pulley sheave contact surface **18**. The distance surface **41** in its entirety is situated below the supporting surface **16**, and, in the shown example, extends substantially parallel to the supporting surface **16**. Furthermore, the distance surface **41** is connected to the curved transition surface **17** through a concave portion **42**, and to the pulley sheave contact surface **18** through a rounded off surface **43**. In this example, the transverse element **10** is rounded off relatively sharply, wherein a relatively small rounding-off radius is applied, at the connection of the distance surface **41** to the pulley sheave contact surface **18**. This is not essential; the transverse

element **10** may be rounded off less sharply than in the shown example at this connection of the distance surface **41** to the pulley sheave contact surface **18**.

The tangent plane **26**, which touches the circumferential surface **25** of the transverse element **10** at both the basic portion **13** and the top portion **15**, touches the basic portion **13** at the rounded off surface **43**. In **Figure 4**, the tangent plane **26** is depicted by means of a dash and dot line. A tangent line between the tangent plane **26** and the rounded off surface **43** is indicated by the letter B. In **Figure 4**, it can clearly be seen that the tangent line B is situated at a lower position than the tangent line A. According to an important aspect of the present invention, the distance between the tangent line B and the pulley sheave contact surface **18** is as small as possible.

When a relatively large collision element touches the transverse element **10** at a place which is also touched by the tangent plane **26**, protrusions are developed on the distance surface **41**. The height difference between the supporting surface **16** and the distance surface **41** can be considerably larger than the height of these protrusions, so that the protrusions are prevented from protruding above the level of the supporting surface **16**.

It is also apparent from **Figure 4**, that in the transverse element according to the state of the art, a distance between the supporting surface **16** and the tangent line A, which is measured along the surface, is smaller than a distance between the supporting surface **16** and the tangent line B, which is measured along the surface, in the transverse element **10** according to the present invention. Consequently, in the latter transverse element **10**, it is not possible for protrusions to develop at the supporting surface **16** itself. Due to this fact and the above-described fact that the protrusions do not protrude above the level of the supporting surface **16**, damage of the rings **8** can not occur when transverse elements **10** according to the present invention are applied. This is an important advantage with respect to the state of the art.

A suitable value of the dimension of the distance surface **41** in the horizontal transverse direction is 0.2 mm. In case of such width of the distance surface **41**, it is ensured that it is not possible for protrusions to be developed at the transition surface **17** and/or the supporting surface **16** as a result of a collision between the transverse element **10** and a relatively large collision element according to the tangent plane **26**.

Assuming a certain width of the rings **8**, an upper limit for the dimension of the distance surface **41** in the horizontal transverse direction is determined by the fact that the dimensions of an

unsupported end of the rings **8** have to remain between limits, because otherwise breaking of the rings **8** may occur.

With respect to the determination of a suitable value of the height difference between the supporting surface **16** and the distance surface **41**, two factors play an important role. The height difference may not be so small that the protrusions on the distance surface **41** are capable of touching the rings **8**. On the other hand, it is important that the height difference remains between limits, so that the pulley sheave contact surface **18** keeps a surface which is as large as possible. Accounting for these factors, it has appeared that 0.2 mm is a suitable value for the height difference between the supporting surface **16** and the distance surface **41**.

In the transverse element according to the state of the art, the transition edge region **40** exclusively comprises the curved transition surface **30**, which has a convex shape. Conversely, in the transition edge area **40** of the transverse element **10** according to the present invention, more than one curved portions may be distinguished. In the shown example, the transition edge region **40** comprises two convex portions, wherein a first convex portion is connected to the supporting surface **16**, and comprises the curved transition surface **17**, and wherein a second convex portion is connected to the pulley sheave contact surface **18**, and comprises the rounded off surface **43**. Furthermore, the transition edge region **40** comprises the concave portion **42**, which is located between the first convex portion and the second convex portion.

In comparison with the tangent plane **26** which touches the circumferential surface **25** of the transverse element **10** at both the second convex portion and the top portion **15**, an imaginary tangent plane (not shown) which touches the circumferential surface **25** at both the first convex portion and the top portion **15**, is situated more to the inside, *i.e.* closer to the neck portion **14**. The tangent line **B**, along which the tangent plane **26** touches the transverse element **10**, is situated outside of the range of the tangent plane touching the first convex portion. A relatively large collision element will only be capable of touching the transverse element **10** along the tangent line **B**, it will not be capable of touching the curved transition surface **17**. In this way, protrusions are prevented from developing on the supporting surface **16**, and protrusions are also prevented from developing at such a place on the curved transition surface **17**, that these protrusions protrude above the level of the supporting surface **16**.

It will be clear to a person skilled in the art that the scope of the present invention is not limited to the examples discussed in the foregoing, but that several amendments and modifications thereof are possible without deviating from the scope of the invention as defined in the attached claims.

Many alternatives exist with respect to the design of the transverse element **10** at the transition of the supporting surface **16** to the pulley sheave contact surface **18**. Within the scope of the present invention, it is important that an imaginary tangent plane **26**, which touches the circumferential surface **25** of the transverse element **10** at both the basic portion **13** and the top portion **15**, does not touch the supporting surface **16**, and also does not touch the curved transition surface **17**. When, as a result of a collision between the transverse element **10** and a relatively large collision element, protrusions are developed, these protrusions are prevented from inflicting damage on the rings **8**. In such case, these protrusions are located at a place at which it is not possible that the protrusions come into contact with the rings **8**.

The distance surface **41** may be completely flat, as is the case in the shown example, but may also be curved, wherein the value of the radius of curvature may vary along the distance surface **41**. When the distance surface **41** is completely flat, it is not necessary that the distance surface **41** extends substantially parallel to the supporting surface **16**. Furthermore, the distance surface **41** may comprise more than one surface portions, which extend in different directions.

The value of the radius of curvature of the curvature of the transition surface **17** may vary along the transition surface **17**. In a comparable way, with respect to the value of the rounding-off radius of the rounded off surface **43**, it is true that this may vary along the rounded off surface **43**.

An important aspect of the present invention is that the supporting surface **16** and the curved transition surface **17** connected thereto are situated at a distance from the tangent plane **26** which touches the circumferential surface **25** of the transverse element **10** at both the basic portion **13** and the top portion **15**.

Thus, the present invention provides a transverse element **10** for a push belt **6** for a continuously variable transmission **1**, which comprises a supporting surface **16** for supporting a carrier **7** of the push belt **6**, and a pulley sheave contact surface **18** for contacting pulley sheaves of the continuously variable transmission **1**.

A curved transition surface **17** is connected to the supporting surface **16**, whereas a distance surface **41** is located between this transition surface **17** and the pulley sheave contact surface **18**. The distance surface **41** is positioned lower than the supporting surface **16**. When the transverse element **10** collides with a relatively large collision element, protrusions may be developed exclusively on the distance surface **41**. These protrusions are not capable of inflicting damage on a carrier **7** which is to be laid on the supporting surface **16**, because these protrusions do not protrude beyond the level of the supporting surface **16**.